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THE EFFECTS OF RADIATION ON THE DEVELOPMENT OF *TRICHINELLA SPIRALIS*

WITH RESPECT TO ITS APPLICATION TO THE TREATMENT OF
OTHER PARASITIC DISEASES

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Since radium has been shown by biological experiment to have a pronounced effect on the development of the germ cells of various species, the possibility of its utilization in the destruction or even in the emasculation of certain parasites for which there is at present no efficient remedy appears worthy of consideration. It was thought that radium might be employed to advantage in the treatment of cases of schistosomiasis in which the bladder is involved, several of which have been under the authors' observation for a considerable period of time. Although this condition is of common occurrence in certain parts of the world and although it is frequently attended with serious complications, up to the present time no successful form of treatment has been discovered. Since the inflammation in this disease is produced by the presence of the ova in the tissues and since the worms from which the latter are derived, are situated in close proximity to the mucous surface of the bladder, this mode of attack seemed to be especially appropriate. It did not appear justifiable, however, to undertake the treatment of human cases without a certain amount of preliminary experimentation.

While the use of Roentgen ray for the treatment of schistosomiasis has been suggested,¹ there appears to be an advantage in the use of radium or its emanation in this disease, for the bladder wall in which the worms are situated may be radiated directly from its inner surface and rays of shorter wave length may be utilized than is possible with the Roentgen rays. According to Packard (quoted by Abbe, 1914) the beta rays are more effective than the gamma rays in retarding the development of certain species.

1. The advisability of employing the x-ray therapeutically in this disease was discussed by Doctor R. Gonzales Rincones of Venezuela at the recent Pan-American Scientific Congress at Washington.

In the following experiments radium emanation was employed as follows:

1. To radiate from the outside the abdomen of rats previously fed with the cysts of *Trichinella spiralis*.

2. To radiate muscle containing encysted larvae of this parasite.

3. To radiate the worms directly during their development in the intestine by feeding minute glass tubes containing radium emanation.² Radiation was accomplished in several ways and further details will be presented with the account of each experiment.

Technic.—The effects of radiation on the parasite were judged by either the failure of the larvae to develop in the intestine of rats and mice or by abnormalities in their development. It was thus important to determine the number of worms present in the intestine and also to note any retardation in their differentiation or growth. In order to count the worms, the intestine of the animal to which the larvae had been fed was cut into pieces of from 3 to 4 cm. in length. These were each placed on an ordinary microscopic slide, opened with fine scissors, and by fixing one end of the piece with tweezers the mucosa was completely stripped from the muscular wall by several light sweeping strokes with the edge of a scalpel. The material obtained, i. e., mucosa and softer portions of the intestinal contents, was spread slightly, and then pressed gently beneath a large 22 by 40 mm. cover glass. With a microscope equipped with a mechanical stage, all the worms in such preparations may be readily observed and counted. Since the material is flattened into a thin film the anatomy of the worms is clearly apparent so that an accurate enumeration of the sexes may readily be made. In the earlier experiments equal amounts of muscle taken from corresponding portions of the body of an infected animal were used for infecting the radiated and the control series, respectively. Since this procedure furnished only approximately equal dosage in the later experiments with mice, the cysts contained in strips of diaphragm were counted and an equal number fed to each of a series of animals.

Observations made during the course of this study failed to confirm certain statements, which occur quite generally in standard works, concerning the anatomical distribution of *Trichinella spiralis*, the ratio of the sexes, and the span of life of the adult male and female of this species.

Distribution in Rats and Mice.—Trichinellae are said to mature in the duodenum and jejunum and it might be inferred that the adults are confined to the first portion of the intestine. In the course of the

2. The authors are indebted to Doctor William Duane for collecting and measuring the radium emanation used and also for suggestions as to dosage, filtration, etc.

following experiments the worms were comparatively rarely present in the first portion of the small intestine of rats and mice, but were found in great numbers throughout the remainder. They not infrequently occur also in the cecum and colon of mice and occasionally in the large intestine of rats. It appears probable that the small size of these host species may account for the presence of the worms in the large intestine since no great extent of gut would have to be traversed before reaching the cecum.

Sex Ratio.—According to Stäubli (1909), great discrepancies with respect to this point are found in the statements of different authors. Thus Leuckart reports the females as greatly in excess of the males, in one instance in a 10:1 or 20:1, and in another instance in a 6:1 ratio. Zenker calls attention to the difficulty in finding the males on account of their smaller size. Askanazy, on the other hand, finds the males greatly in excess in the intestinal contents, but this was thought to be due to the fact that the females burrow into the mucosa, while the males remain free. Ostertag claims that the males and females are originally present in equal numbers, but that the former after copulation diminish in number, so that after 10 to 14 days only females are present. Both sexes were observed by Pagenstecher 56 days after ingestion. Stäubli notes great variation in the sex ratio in different cases with respect not only to the mature adults, but also to the encysted larvae the sex of which he is able to distinguish. He is unable to account for this lack of uniformity in the relative number of the sexes.

In order to avoid error in estimating the relative number of males and females it is important to examine the material in such a way that none will be overlooked. The males, on account of their smaller size, are not so readily detected, except with the aid of a microscope. Thus in 100 worms picked out with the naked eye from a suspension of intestinal contents and mucosa, not a single male was found; whereas a count made with the microscope of samples of the same material showed 31 per cent males.

Counts of 100 or more worms from the intestines of four rats of the present series showed the percentage of males to vary from 31 to 41 per cent seven or eight days after injection. In a total of 446 worms, 160, or 36 per cent, were males. An approximation of a 1:2 ratio was thus found in these animals. Rats killed seventeen or eighteen days after ingestion of infected muscle showed practically the same ratio, although only few worms were found. It is of interest to note that in one rat in which a single male was found unaccompanied by any females, numerous larvae were found in the striated muscles showing that this male had outlived one or more females which had been present.

EXPLANATION OF PLATE

Fig. 1.—A cross section of male and female *Schistosoma haematobium* situated in a distended vein at the juncture of the submucosa and muscular wall of the bladder. This vessel is evidently occluded by the inflammation which the worms' presence has excited. The intestinal ceca of the female are distended with deeply stained material to the right of which is the ovary.

Fig. 2.—Male and female *S. haematobium* in longitudinal section. In the upper portion of the sectioned worms to the right a row of eggs is visible in the tubular uterus of the female. The acetabulum of the male is apparent, directed inwardly near the anterior extremity of the worms at the left. These worms are situated in veins beneath the submucosa, in this instance 4 or 5 mm. from the surface of the mucosa. The inflammatory changes in the latter are apparently due to the presence of numerous ova, for these are found surrounded by collections of exudate with which they are evidently discharged during the contraction of the bladder. Many ova also fail to reach the surface but become imbedded in the tissue where they are eventually destroyed, the shells persisting as foreign bodies.

PLATE

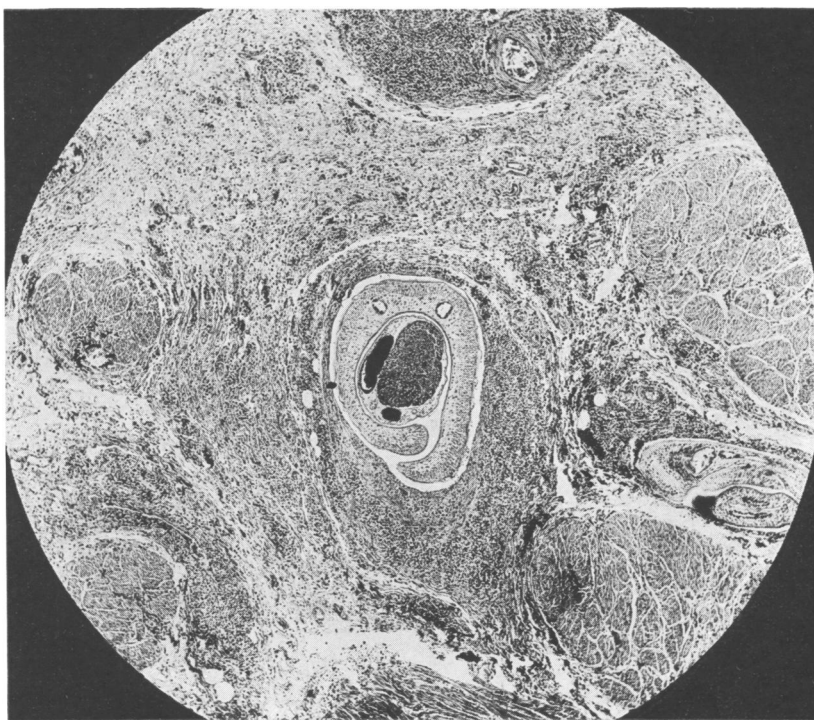


Figure 1

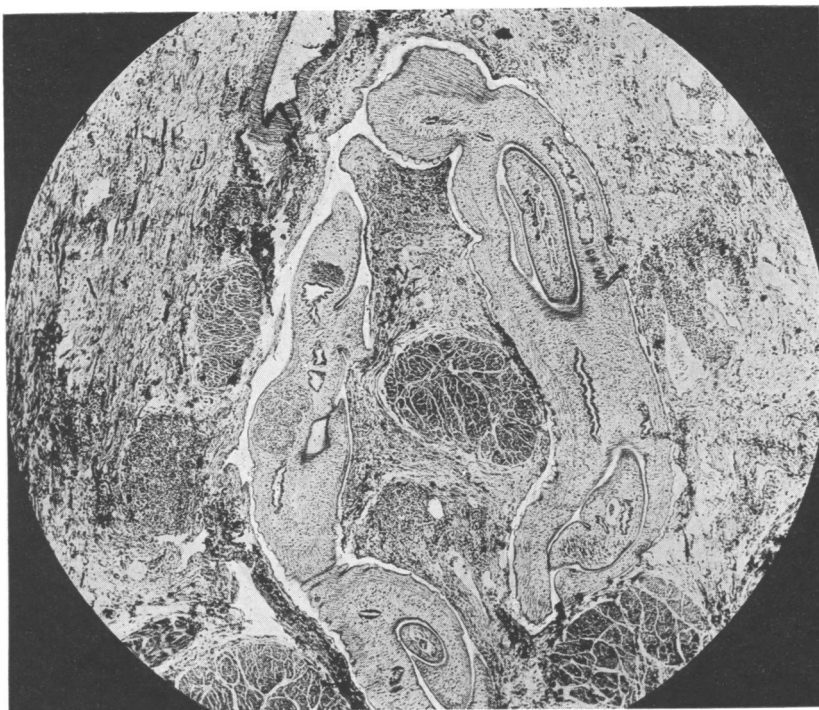


Figure 2

In mice fed with relatively small numbers of encysted larvae and killed four, five, six, seven and nine days later, there is considerable variation in the sex ratio, evidently on account of the small numbers of adult worms present in each animal. Including trichinellae subjected to radiation, together with those of the control mice, there were 516 counted, and 159, or 30.8 per cent of these were males. Considering the non-radiated separately, there were 167, of which 42, or 25 per cent, were males. There was no marked diminution in the number of males from the fourth to the seventh day, and the number counted on the ninth day is too small to be of significance. The sex ratio of one male to two females is thus also approximated for this parasite in the mouse.

Disappearance of Adult Worms from the Intestine.—Whereas the males are said to diminish in number after copulation, which is accomplished by the second or third day after ingestion, it is stated that the females may persist for five weeks or longer. Cohnheim claims to have observed trichinellae in great numbers up to the seventh week; Kratz found them seventy-seven days, and Leuckart twelve weeks after ingestion. In experimental animals the embryos are said to be liberated from adults for five to seven weeks after the ingestion of trichinous meat (Fantham, Stephens, and Theobald, 1916). It would appear from the findings in the rats of the following experiments that the adult worms disappear much earlier than the above observations by various authors would indicate. The data collected are presented in the following table.

TABLE OF RESULTS

Rat	Period of Infection	Number of Adult Trichinae	Males	Females	Remarks
Wild 4853A.....	19 days.....	None.....	.....	.....	Only a portion of intestine examined
Wild 4853B.....	19 days.....	None.....	.....	.....	Only a portion of intestine examined
White 4965 A.....	25 days.....	Present....	Present....	Present....	
White 5590.....	7 days.....	Numerous..	31.5%	68.5%	146 counted
White 5592.....	17 days.....	One.....	.....	One.....	Entire intestine examined
White 5618.....	7 days.....	Estimated 600	36%	64%	100 counted
White 5619.....	8 days.....	Estimated 800	37%	63%	100 counted
White 5620.....	8 days.....	Estimated 1,000	41%	59%	100 counted
White 5622.....	18 days.....	None.....	.....	.....	Ten inches of small intestine examined
White 5623.....	18 days.....	One.....	One.....	.....	Ten inches of small intestine examined
White 5624.....	18 days.....	Two.....	.....	Two.....	Ten inches of small intestine examined
White 5625.....	18 days.....	None.....	.....	.....	Ten inches of small intestine examined
White 5626.....	18 days.....	None.....	.....	.....	Ten inches of small intestine examined

Numerous larvae were found in the skeletal muscles of all the negative rats showing that the adult worms had been present in the intestine of each. In one rat adult worms of both sexes were still present twenty-five days after ingestion, but in general their paucity or absence is notable in the animals killed later than the sixteenth day. In the last group, each animal of which was fed an equal amount of trichinous muscle, the most striking differences are shown with respect to the number of worms present in the rats killed seven and eight days and in those killed eighteen days later. This would indicate that this parasite's span of life in the intestine of the rat is rarely over three weeks, although there may occasionally be individuals persisting longer.

In the following experiments radium emanation was used. Since this substance is transformed at a known rate, the amount of radiant energy available is constantly diminishing (approximately one half in four days), so that the dosage is greatest at the beginning of the exposure.

1. RADIATION OF THE ABDOMEN FROM THE SURFACE OF THE BODY

In considering the effects of radiation on *Trichinella spiralis*, both the failure to develop as determined by the number present and the retardation of development as indicated by the absence of worm-shaped embryos in the females seven days after feeding were taken into account. Although various degrees of maturity were met with at this time, the presence or absence of worm-shaped embryos could be readily determined and served as a useful, although arbitrary, index. Small and evidently poorly developed males were also met with, but since they furnish no prominent feature by which their stage of development could be judged, they are not in this respect taken into consideration.

EXPERIMENT 1

February 18, 1916. Equal amounts of muscle containing encysted larvae were fed to four healthy rats and two of these served as controls, while the other two were radiated from the surface of the abdomen. Radium emanation enclosed in capillary glass tubes with 0.1 mm. of steel, 1 mm. of silver and a layer of adhesive plaster for filtration was used. This applicator was moved each day to a new area on the abdominal wall, from the entire extent of which the fur had been removed. One rat, 5591, which was radiated in this manner with a tube of 8.8 millicurie strength from the second day following ingestion of trichina, died six days later; that is, seven days after infection. An additional tube containing 6.4 mc. was added five days after feeding and two days before death. Another rat, 5593, was radiated in a similar manner with a very weak tube (3 mc.) from the sixth to the tenth day and with a 9.6 mc. tube from the tenth to the seventeenth day, when it was killed and the number and condition of intestinal trichinae determined.

TABLE OF RESULTS—EXPERIMENTS 1 AND 2

Trichinae- Fed Rat	Treatment	Death	No. of Worms Found			Remarks
			Total	Males	Females	
Experiment 1						
5560	None (control).....	Killed 7 days later.....	Numerous..	31.5%	68.5%	Females 2% without embryos
5561	Ra. 8.8 mc. from 2d day.....	Dead 7 days later.....	Numerous..	33.7%	66.3%	Females, 32% without embryos
5562	None (control).....	Killed 17 days later.....	One.....	.....	One.....	This female was immature
5563	Ra. 3 mc. from 6 to 10th day and 9.6 mc. from 10th day	Killed 17 days later.....	316	31 %	69 %	Worms large and apparently normal
Experiment 2						
5617	Ra. 11.8 mc. from 1st day.....	Dead 7 days later.....	Two.....	.....	Two.....	Neither contains embryos
5618	None (control).....	Killed 7 days later.....	600±	36 %	64 %	Females, 1.5% without embryos
5619	None (control).....	Killed 7 days later.....	800±	37 %	63 %	
5620	None (control).....	Killed 7 days later.....	1,000±	41 %	59 %	
5621	Ra. 2 mc. from 8th day and 15.5 mc. from 11th day	Dead 16 days later.....	31	51.5%	48.5%	
5622	None (control).....	Killed 18 days later.....	None.	.....	.....
5623	None (control).....	Killed 18 days later.....	One.....	One.....	.....
5624	None (control).....	Killed 18 days later.....	Two.....	.....	Two.....	
5625	None (control).....	Killed 18 days later.....	None.....	.....	.....
5626	None (control).....	Killed 18 days later.....	None.....	.....	.....

EXPERIMENT 2

March 10, 1916. Ten normal rats were fed with equal amounts of trichinous muscle mixed with bread and milk. Radiation was commenced at once with Rat 5717, a tube of 11.8 mc. strength being used. This animal was found dead at the end of seven days. Another rat was radiated with a weak tube (2 mc.) from the eighth day and also with a stronger dose (15.5 mc.) from the eleventh day. It died 16 days after infection. The results obtained in both experiments are combined in the table on the preceding page.

While these results failed to demonstrate that radiation is of therapeutic value in the treatment of trichiniasis, they indicate that it appreciably modifies the development of the parasite in the intestine. Radiation after the females have become ripe, that is after the sixth day, fails to affect an earlier disappearance of trichinellae, or to produce distinguishable injury to them. In fact, the worms appear to persist longer and to be unusually large and well developed in the late radiated animals. That larvae had continued to be liberated from the female worms was shown by the presence of very small as well as partially developed worms in the striated muscles of these rats. Although the control rats killed seventeen and eighteen days after feeding on trichinous meat furnish few or no adult trichinellae in the intestine, numerous larvae were found in the skeletal muscles of all showing that infection had occurred.

Early radiation apparently had a greater effect on the development of trichinellae in the intestine. Radiation of the rat's abdomen from the second day after the ingestion of the cysts resulted in a retardation of development as shown by the number of immature females; 32 per cent of these showed no fully formed embryos as compared with 2 per cent in the control animals. Females were observed in the radiated rat which were so backward in their development that they were considerably smaller than normal males, although seven days had elapsed since their ingestion. There appeared to have been no general failure of the immature females to become inseminated, although this may have been accomplished later than normally. In only a few small undeveloped females was the receptaculum seminis not filled with spermatozoa. Subsequent experiments have shown that under normal or ordinary conditions the worms almost without exception are fully developed seven days, and usually six days, after they have entered the alimentary tract. Only a few larvae were found on careful search in the diaphragm of the rat radiated from the second day, whereas they were present in great numbers in the diaphragm of the control rat. Still earlier radiation, that is, from the time of the ingestion of the encysted larvae, appears to be even more effective, and in the animal in which this was carried out only two females, neither of which con-

tained embryos, were found. The three rats which served as controls for this animal each showed numerous well developed worms estimated at 600, 800, and 1,000, respectively.

Since the radiation employed was fatal to three of the four trichinous rats, the possibility that the injury to the host might indirectly affect the life of the parasites may be considered. That changes in the host resulting from radiation do not tend to destroy the worms is shown in the late radiated rat in which adult worms persisted longer than in the controls.

II. THE RADIATION OF ENCYSTED LARVAE BEFORE INGESTION

It appeared important, in order to estimate the dosage appropriate for the employment of shorter radium rays, to radiate the larvae before they were fed to the animals. For this purpose the filtration through the millimeter of silver was dispensed with and capillary glass tubes of emanation enclosed in steel tubes having walls 0.1 mm. in thickness were employed. Under-estimation of the effects of the short rays necessitated repeating the experiment several times. In Experiment 3, which is not presented in tabular form, none of the larvae in meat radiated with a 5.9 mc. tube for six and for three days developed when fed to mice. Control mice fed with untreated meat in every case showed trichinellae when killed later on.

For the purpose of making the observations more accurate, equal numbers of encysted larvae were fed to each animal in all subsequent experiments. The encysted larvae were radiated by wrapping strips of mouse diaphragm around the steel tube containing the emanation, in this way ensuring fairly uniform radiation of all portions of the muscle. The layer of muscle around the steel tube nowhere exceeded 1.5 mm. in thickness. The strips of diaphragm were subdivided when necessary so that an equal number of cysts could be fed to each mouse. This was accomplished by placing the bits of diaphragm in the mouth of the animal and holding the latter until the material was swallowed.

EXPERIMENT 4

April 14, 1916. Twelve mice were employed in this experiment. Two of these served as control animals, being fed each with 40 trichina cysts. The other ten were each fed 40 cysts which had been radiated for different periods with 5.5 mc. of emanation enclosed in a capillary glass tube and filtered through 0.1 mm. of steel. Tissue radiated was nowhere more than 1.5 mm. in thickness. Six of the animals were killed four and five days after this feeding, and a count made of the number of *Tr. spiralis* present in the small and large intestine of each. The other six were allowed to live for a longer period and the muscles were then examined to determine whether infection had taken place.

TABLE OF RESULTS—EXPERIMENT 4

No. Mouse	Larvae Radiated with 5.5 Mc.	Each Fed 40 Larvae	Killed	Mature		Immature		To- tal
				♂	♀	♂	♀	
5699	Control untreated.....	April 14.....	April 20.....	3	10	0	1	14
5700	Control untreated.....	April 14.....	April 21.....	0	10	0	0	10
5691	3 hrs. at 33 C.....	April 14.....	April 20.....	0	0	0	0	0
5692	3 hrs. at 33 C.....	April 14.....	April 20.....	0	0	0	0	0
5693	6 hrs. at 33 C.....	April 14.....	April 20.....	0	0	0	0	0
5694	6 hrs. at 33 C.....	April 14.....	April 21.....	0	0	0	0	0
5695	12 hrs. at 33 C.....	April 14.....	May 4.....	Muscles negative				0
5696	12 hrs. at 33 C.....	April 14.....	May 4.....	Muscles negative				0
5697	24 hrs. at 33 C.....	April 14.....	May 4.....	Muscles negative				0
5698	24 hrs. at 33 C.....	April 14.....	May 4.....	Muscles negative				0
5701	48 hrs. at 33 C.....	April 14.....	May 4.....	Muscles negative				0
5702	48 hrs. at 33 C.....	April 14.....	May 4.....	Muscles negative				0

EXPERIMENT 5

April 21, 1916. Fourteen mice were employed, two receiving untreated cysts, the others receiving equal numbers of cysts which had been radiated for different periods of time at room temperature. The technic employed was the same as that in the preceding experiment but shorter exposures were made. The radiated tissue was nowhere more than 1.2 mm. in thickness. The mice were all killed five or six days after the feeding.

TABLE OF RESULTS—EXPERIMENT 5

No. Mouse	Larvae Radiated with 7.1 Mc.	Each Fed 40 Larvae	Killed	Mature		Immature		To- tal
				♂	♀	♂	♀	
5738	Control untreated.....	April 21.....	April 26.....	0	3	0	1	4
5739	Control untreated.....	April 21.....	April 27.....	2	8	0	0	10
5726	2½ minutes.....	April 21.....	April 26.....	1	1	2	8	12
5727	2½ minutes.....	April 21.....	April 27.....	6	10	0	0	16
5728	5 minutes.....	April 21.....	April 26.....	3	5	3	2	13
5729	5 minutes.....	April 21.....	April 27.....	1	3	0	6	10
5730	10 minutes.....	April 21.....	April 26.....	1	8	2	4	15
5731	10 minutes.....	April 21.....	April 27.....	0	0	0	0	0
5732	20 minutes.....	April 21.....	April 26.....	0	0	0	0	0
5733	20 minutes.....	April 21.....	April 27.....	7	12	0	0	19
5734	40 minutes.....	April 21.....	April 26.....	0	0	0	0	0
5735	40 minutes.....	April 21.....	April 27.....	1	1	0	0	2
5736	80 minutes.....	April 21.....	April 26.....	0	0	0	0	0
5737	80 minutes.....	April 21.....	April 27.....	0	0	0	0	0

It is apparent from the above experiment that radiation for eighty minutes with 7.1 mc. is fatal to the encysted larvae, but the results obtained for the next shorter periods are rather variable, one positive and one negative result being obtained in each of the three successive periods. Radiation for two and one-half and for five minutes appears not to have been markedly injurious. It was thought possible that since certain portions in the length of the steel tube employed were less

radioactive than others, certain portions of the diaphragm exposed may have been subjected to less radiation accounting for the irregularity of the results obtained. On account of this it was considered necessary to repeat this experiment, paying especial attention to the equal radiation of all parts of the material used.

EXPERIMENT 6

May 1, 1916. Ten mice were employed, two served as controls, and the others received equal numbers of encysted larvae radiated for various periods. These were killed four and five days after this feeding and the intestine examined for *Tr. spiralis*.

TABLE OF RESULTS—EXPERIMENT 6

No. Mouse	Larvae Radiated with 6.6 Mc.	Each Fed 40 Larvae	Killed	Mature		Immature		To- tal
				♂	♀	♂	♀	
5749	Control untreated.....	May 1.....	May 5.....	4	0	0	1	5
5750	Control untreated.....	May 1.....	May 6.....	1	3	0	8	12
5747	20 minutes.....	May 1.....	May 5.....	1	0	2	5	8
5748	20 minutes.....	May 1.....	May 6.....	0	0	0	1	1
5745	30 minutes.....	May 1.....	May 5.....	0	0	0	0	0
5746	30 minutes.....	May 1.....	May 6.....	0	0	0	0	0
5743	40 minutes.....	May 1.....	May 5.....	0	0	0	0	0
5744	40 minutes.....	May 1.....	May 6.....	0	0	0	0	0
5741	60 minutes.....	May 1.....	May 5.....	0	0	0	0	0
5742	60 minutes.....	May 1.....	May 6.....	0	0	0	0	0

From the three preceding experiments the lethal dosage of radiation for encysted trichinae is determined. They are made non-infectious for mice by radiation with 6.6 mc. filtered through thin glass and 0.1 mm. of steel in an exposure of thirty minutes. The cysts exposed were at a distance of not over 1.5 mm. from the source of radiation. It would be of interest to learn more concerning the effects of this amount of radiation on encysted larvae whether they are killed outright, or the cyst made more resistant to the digestive juices or the larvae injured to such an extent that they are passed from the alimentary tract before they can recover sufficiently to maintain their existence. In all of the present experiments only the immediate result of radiation as shown by the absence or by the arrested development of worms, has been determined. It would be of considerable interest to note whether any remote or late changes are brought about, but this probably would be more readily determined in a free-living rather than in a parasitic species.

III. THE DIRECT RADIATION OF TRICHINELLA SPIRALIS FROM THE INTERIOR OF THE ALIMENTARY TRACT

Since the short rays were found to be effective in the destruction of the larvae the direct radiation of the worms from the interior of the intestine was next undertaken. Through radiating the interior of

the intestine by means of tubes of emanation fed to the animal it was hoped to utilize very short rays. The movement of the intestinal contents was expected to prevent undue burning of the mucosa of the small intestine and the incorporation of the tube in more or less solid fecal material was hoped to protect the wall of the large intestine from serious injury. Minute tubes of emanation were prepared by Doctor Duane. Since these measured only from 2 to 3 mm. in length and a fraction of a millimeter in diameter, they could be readily introduced into the stomach of the mouse. In order to accomplish this, a large syringe needle, the point of which had been ground off square, covered with paraffin and dipped in oil so that it could be readily passed down the esophagus of the mouse, was used. The emanation tube having been placed in the needle, it was forced by a plunger into the stomach of the mouse. It could readily be determined at any time whether the tube had been passed from the intestine or was still in the body of the mouse by placing the latter on the ionization chamber of the measuring apparatus.

EXPERIMENT 7

June 27, 1916. Nine mice were each fed 40 trichina cysts in bits of mouse diaphragm. Minute glass tubes of emanation were introduced into the stomach of three of these, one receiving a tube on the first day, another on the second day, and another on the third day.

TABLE OF RESULTS—EXPERIMENT 7

No.	No. Fed	Radium Fed	Died	No. Tr. Spiralis
5803	80 cysts.....	3.1 mc. 7 hours later.....	Killed 5 days....	24 (4 immature)
5804	80 cysts.....	4.1 mc. 28 hours later.....	Dead 6 days....	57
5805	80 cysts.....	3.2 mc. 51.5 hours later.....	Dead 6 days....	46
5806	80 cysts.....	Control.....	Killed 5 days....	33
5807	80 cysts.....	Control.....	Not examined	
5808	80 cysts.....	Control.....	Not examined	
5809	80 cysts.....	Control.....	Not examined	
5810	80 cysts.....	Control.....	Not examined	
5811	80 cysts.....	Control.....	Not examined	

In the first mouse (5803) the tube failed to pass from the intestine during the four days and fourteen hours which elapsed before it was killed on account of its weak appearance. The tube fed the second mouse (5804) was still in its body after three days, but had been passed when found dead two days later. The tube fed the third animal (5805) was passed within forty-eight hours. Notwithstanding the small dosage, 3.2 mc., for so short a period, this animal died before the end of four days after its introduction. This mouse presented a reddened area in the wall of the large intestine. The others showed no local effects of the radiation, but all showed a striking shrinkage in the size of the spleen so characteristic of radiated animals. These results show unmistakably that in the mouse even fatal doses of radium emanation acting

from the interior of the intestine fail to prevent the development of *Tr. spiralis*. It is quite apparent that this parasite is not especially vulnerable to rays which have an immediate destructive influence on the lymphoid tissue of the host.

The results of the foregoing experiments are thus rather discouraging with respect to the application of radiation to parasitic worms. It is rather remarkable that *Tr. spiralis* is so little affected after commencing its development within the body when it, in its encysted state, is so quickly destroyed by radiation outside the body. Whether internal radiation would accomplish more in larger, more resistant animals remains to be determined. The acceleration of the passage of radium emanation through the large intestine by the employment of a cathartic might be of value, but was not tried in these experiments. It would appear, however, that, under the conditions of the above experiment, radiation destroys the resistance of the animals before the parasite is markedly affected.

These results do not, therefore, furnish an experimental basis for the treatment of schistosomiasis by radiation from the interior of the bladder. Although this treatment would for some reasons appear especially applicable to this disease, it would probably be impossible, with the short rays, to reach all the adult worms, for they are frequently situated at a considerable distance from the surface of the mucosa. Treatment of this disease by radiation, although justified on theoretical grounds, must for the present be regarded as experimental in character, and, even if no untoward results occur, it will be difficult to determine just what has been accomplished. On the other hand, the localization of the worms and the relatively large size of the host are distinctly in favor of this form of treatment. The fact that it is a disease frequently attended with serious complications would appear to warrant cautious treatment by radiation, provided that the experimental nature of the treatment is explained to the patient, and provided that changes in the local condition may be followed by cystoscopic examination and by observations with reference to the number of ova discharged in the urine.

SUMMARY

By radium radiation from the surface of the abdomen of the rat the injury of fully developed *Trichinella spiralis* has not been accomplished. These worms appeared well developed and persisted longer than in controls.

Similar treatment from the second day after the ingestion of cysts has apparently resulted in a retardation of development, 30 per cent of the females being immature.

In a rat radiated in this manner from the time it was fed trichinous meat, only two immature worms were found seven days later, indicating that radiation of the larvae before they have entered upon their period of development free in the intestine is fatal to them.

The radiation of encysted larvae with 6.6 mc. of emanation, 0.1 mm. steel filtration, at a distance of not over 1.5 mm. for thirty minutes renders them non-infectious for mice.

Radiation from the interior of the intestine—employing emanation in minute glass tubes for the utilization of short rays—in amounts sufficient to cause the death of the mice employed has not prevented the development of *Tr. spiralis*.

These results fail to furnish an experimental basis for the treatment of schistosomiasis by radiation, so that if the latter is attempted it should be regarded as an experiment rather than an approved mode of procedure.

Observations on the life history of *Trichinella spiralis* made in the course of these experiments indicate that certain points emphasized in books of reference do not apply to the development of this parasite in rats and mice.

Trichinella spiralis is found only in small numbers in the duodenum and jejunum of rats and mice which show great numbers in the lower portion of the small intestine. It is also occasionally found in the cecum and large intestine.

The life of this parasite is comparatively short in the rat, and it is found to have disappeared or is present only in small numbers eighteen days after infection.

No evidence has been obtained that the males disappear early in the infection. A sex ratio of 1 ♂ : 2 ♀ observed six and seven days after infection has shown no marked change for the ten days following. A male *Trichinella* has been found in a rat from which all females had disappeared.

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